How to link mobiles to form a repeater

Simple repeater configurations in Alaska support radio communications links as long as 60 miles. Here's how to build a link for use with two Motorola Maxtrac radios. Similar links can be designed for other units.

By Carlton L. Tedrick, P.E.

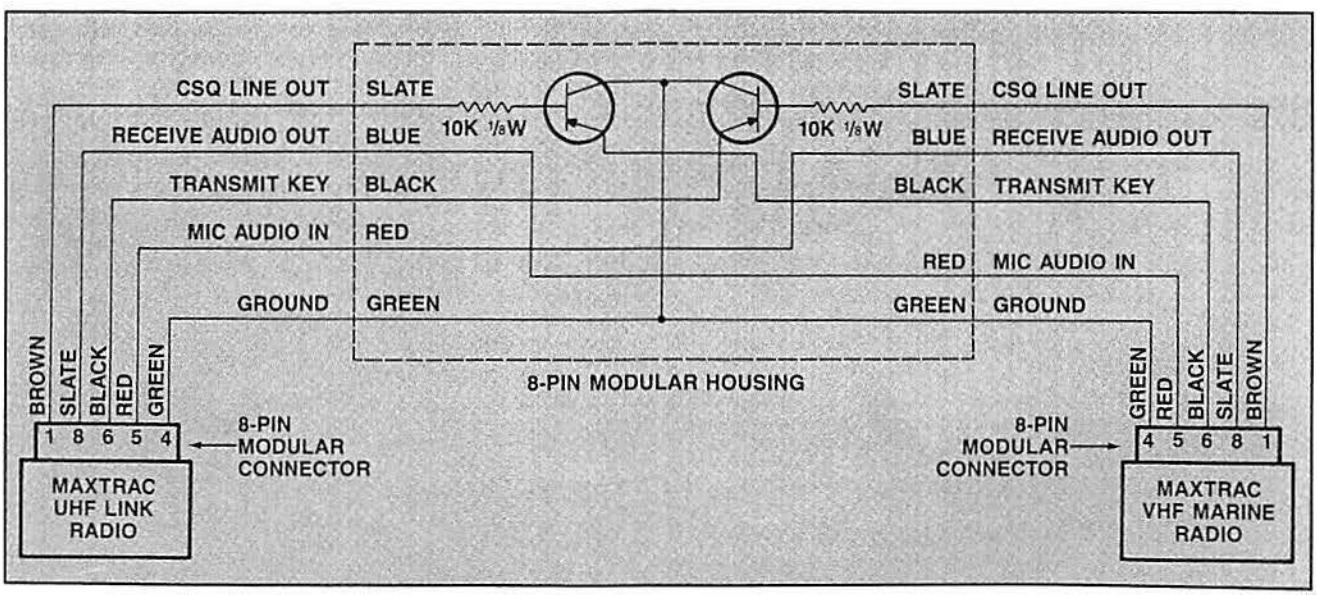
During a consulting assignment in Alaska, a simple, reliable and effective method of linking two mobile, under-dash transceivers in a back-to-back repeater configuration was needed. Commercially made devices are available to accomplish the task. But because they are designed to be universal, they tend to be complex, and many are difficult to adapt to specific needs. The immediate requirement was for a method of reusing a number of Motorola Maxtrac mobile units.

Tedrick, a consulting engineer, owns Communications Service and Engineering, Nacogdoches, TX. He also is an independent contractor with Lockard & White consulting telecommunications engineers, Houston. This information first appeared in Lockard & White's *Network*.

The first task was to identify a control point in each receiver that would provide a change of logic state when a signal opened the squelch circuit. Such a point was found at pin 2 of J6 in the Maxtrac. A small jumper was run from that point to the unused pin 1 of J11 on the front panel. This jumper provides a change of state from 4Vdc to 0Vdc when the squelch opens. A small, general purpose transistor completes the transmitter keying circuit.

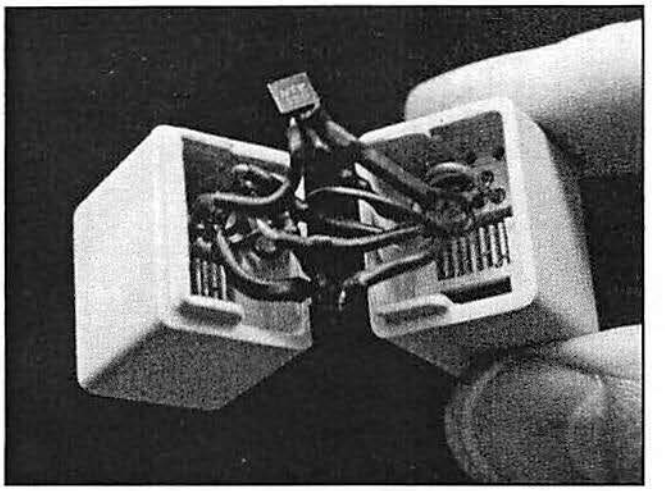
Locating an adequate point from which to derive received audio to drive the microphone input of the adjacent radio was next. The transmitter's input sensitivity is approximately 80mV rms for 60% carrier deviation. An oscilloscope was used to look for suitable fixed audio output points in the receiver. *Fixed* is the key word because any *variable* point, such as the volume control center tap, invites trouble. The signal level at the high side of the volume control was too high, and the handset output produced a level that was much too low. A 1,800Ω, ⅛W resistor applied between pins 1 and 4 of J8 provided just the right level of audio to feed the microphone input from the handset audio connection of J11.

This audio point is *after* the de-emphasis circuitry, as it should be to drive the microphone input circuitry of the adjacent transmitter. Once the linkup was complete and set up for bench testing, the transmitter deviation was set to produce a "one-to-one" ratio—that is,



This diagram shows how to wire the double-ended female 8-pin RJ modular connector and the RJ connectors that plug into the Maxtrac radios.

RJ-type modular connectors are used in the Maxtrac radios, so a double-ended female 8-pin RJ modular connector device was chosen to house the link. This forces compact wiring, and short leads are required in such configurations to reduce the possibility of stray RF pickup.



The double-ended female RJ connector is snapped apart carefully and the two transistors and cross-connections are soldered in place. Heat-shrink tubing was used on each connection because of small working quarters.

a received deviation of 3kHz produced a deviation of 3kHz on the opposite transmitter. Take into consideration continuous-tone controlled squelch system (CTCSS) signaling and its effect on overall deviation settings when making these adjustments.

These modifications were performed on both radios to be used in the linked configuration. They are minimal modifications. Nevertheless, they allow the Maxtrac radios to continue to be used as conventional mobile units, in most instances. These modifications, though, will cause increased handset audio when a handset is used.

Development of a *simple* and *reliable* "link" device to connect the two radios was necessary. RJ-type modular connectors are used in the Maxtrac radios. A double-ended female 8-pin RJ modular connector device was chosen to house the link. This forces compact wiring, and short leads are required in such configurations to reduce the possibility of stray RF pickup. This type of wiring permits ordinary flat telephone cable and crimp-on RJ connectors to be used, creating a virtually foolproof interconnection arrangement. Remember: *Keep all leads short.*

The double-ended female RJ connector is snapped apart carefully and the two transistors and cross-connections are soldered in place. Heat-shrink tubing was used on each connection because of small working quarters.

All that remains is to build two *extremely short* 8-conductor cables with 8-pin male RJ connectors crimped onto the ends. These cables should be assembled with the connectors in the standard configuration, with locking tabs on all connectors facing in the same direction. This assures proper interconnection and polarity.

With construction complete, benchtesting is in order. Here is where the foolproof nature of the design becomes apparent. You can connect the link device to the radios without regard to orientation or polarity—it should work fine. Remember, though, this particular device is designed to work with *two identical radios* (Maxtracs in this case), and probably will not work with different radios. A similar arrangement probably can be developed for similar radios from other manufacturers.

With construction complete, benchwork testing is in order. Here is where the foolproof nature of the design becomes apparent.

One minor drawback should be noted. The CSQ line used to control the adjacent transmitter push-to-talk (PTT) is at a logic high when the squelch is closed (no signal received). The CSQ line goes to logic low when the squelch opens (signal received). If one of the radios fails or loses power, the same condition occurs—logic high goes to logic low. This will key the PTT lead of the adjacent transmitter, resulting in an unmodulated carrier on the air.

To prevent this from becoming a problem, the Maxtrac's time-out interval should be programmed for less than three minutes. Then, if one radio fails or loses power, the "dead" carrier will be limited to the timer interval. The transmitter then will shut down until the problem is corrected.

Circuitry to prevent the PTT line from being keyed when one radio fails or loses power can be designed, but it would complicate the link arrangement and would require more extensive modification of the radios. The simplicity of the system as described outweighs the minor drawback.

Several of these linked radio pairs are deployed in Prince William Sound and the Gulf of Alaska at unattended, solar-powered mountaintop sites. They appear to perform as intended. They do not exhibit any sensitivity to nearby RF fields from other radios. This is an inexpensive solution to a unique problem, one that may be useful to others.

Mobiles linked as repeaters: Improving the Maxtrac combo

Based on modifications described in a November 1990 article, new circuit modifications improve push-to-talk (PTT) and continuous-tone-controlled squelch system (CTCSS) operation for Maxtrac radios configured as a repeater.

By William Plante, N.C.E.

"How to Link Mobiles to Form a Repeater" by Carlton Tedrick in the November 1990 issue showed how to link two Motorola Maxtrac series radios. I have used this configuration with success, but the design that the article describes has drawbacks, including the false key-up of continuous-tone-controlled squelch system (CTCSS) tone.

If radio A were programmed for CTCSS receive only and if it were on hook, any carrier received would key up radio B, yet no audio would pass from radio A to radio B because the CTCSS prevents it. A modification that I have used improves the linking design with respect to both the false key-up and the use of CTCSS.

Changes include the use of an NPN transistor and a 10,000Ω resistor inside the radio to form a push-to-talk (PTT) switching circuit. This switching circuit is driven from the microprocessor's receiver mute (Rx mute) line. With the circuit, the microprocessor of radio A controls the PTT circuit of radio B. The conversion allows full use of CTCSS control of both radios.

Plante lives in Farmingdale, ME. He is a NARTE-certified engineer (N.C.E.). NARTE is the National Association of Radio and Telecommunications Engineers.

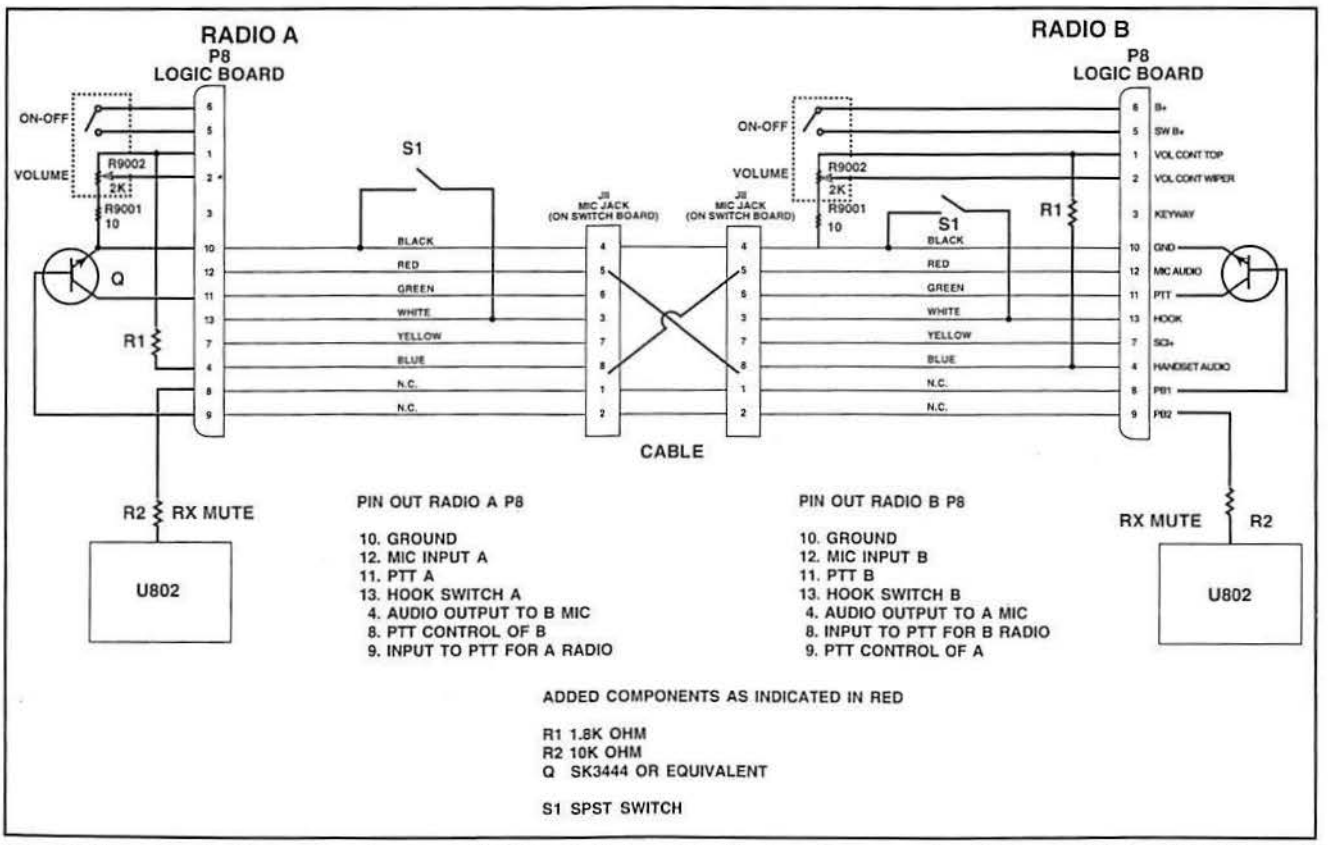


Figure 1. This schematic diagram shows how to modify Motorola Maxtrac 300 radios to work as a repeater with improved PTT and CTCSS control. Components added to the circuitry are indicated in red.

For example, when the microphone is on hook (or switched by S1), only received signals with a proper tone activate the other radio's PTT circuit. If non-CTCSS operation is required, the operator only has to take the microphone off hook to key the other radio's PTT line with a carrier only. A simple toggle switch (S1) can be added as shown in Figure 1 on page 68 to control hook-switch operation, or a "T" connector could be placed on the microphone jack. (I installed the switch on my unit.) The internal transistor provides a PTT control input to the radio on which it is installed, and the transistor is driven by the other radio. (See Figure 1.) This arrangement has been in operation quite some time and works well.

The pin number for the Rx mute line of U802 for the Maxtrac radio is not shown because the number is different in various models of the logic board. Look for the Rx mute label on the schematic provided for your radio to identify the pin. The 10K resistor connects directly to the microprocessor without any other resistors in series to isolate the Rx mute function from the radio's other functions. I used an SK3444 transistor for the switching, but any comparable transistor can be used. Placing the components within the radio case makes the installation clean. Only two wires must be reversed in the jumper cable connecting the two radios. The audio lines and audio dropping resistor are the same as those described in the original article.

Each radio should be labeled either A or B, because the cross-connection difference requires them to be used in pairs. This labeling has not been a problem in my installation, because radios on different frequency bands are used for radios A and B. In our system, A is VHF lowband; B is UHF.

I did not try other series of Motorola radios, such as the Radius product line, but this conversion also should be adaptable to them. Be aware that any modifications to equipment may void the warranty on that product. As with other equipment modifications, the author assumes no liability or responsibility for results of this modification.

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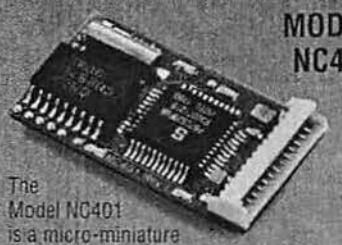

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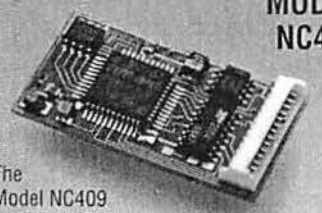

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